Hydrostratigraphic Unit (HSU) Map-Unit Definitions and Geomap-Unit Correlations, San Francisco River (SFR) Basin, New Mexico and Arizona
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Introduction: In addition to work by Trauger (1972-Grant County) and Basabilvazo (1997-Catron County), the hydrogeologic framework of the below-listed map-units has been adequately described in only 4 partsof the SFR Basin: 1) Reserve subbasin (Crews 1994), 2) the Alma subbasin (Houser 1987,1994; Ratté 1989, 2008), 3) the northern Mangas subbasin (Mack 2004, Mack and Stout 2004), and 4) the Clifton-Morenci, AZ area of Greenlee County (Ferguson and Enders 2000, Ferguson et al. 2000). The Hydrostratigraphic-Unit (HSU)-Lithofacies-Assemblage (LFA) classification is adapted from Hawley and Kernodle (2000), and Hawley et al. (2000).

Post-Gila Group HSUs (Valley-Fill and Piedmont-Slope Deposits, and Basaltic Volcanics)

RG-Channel, floodplain, and low-terrace deposits of major perennial-intermittent streams of the San Francisco River basin (including Blue and Tularosa Rivers); mostly Lithofacies-Assemblage (LFA) a1-a2; saturated thickness as much as 60 ft (18m); Holocene and uppermost Pleistocene. Included in NM Statemap unit Qa. *Note: Along with HSU-UMG, forms major basin-fill aquifer system in the SFR basin area*

VA-Valley-fill alluvium (undivided), deposits of larger ephemeral tributaries to major perennial/intermittent streams (RG) and some fluvial-terrace fill; LFA b, with many inclusions of unit RG (LFA a); as much as 60 ft (18m) thick; primarily in the vadose zone, but basal parts may be seasonally saturated or contain "perched-groundwater" bodies; Holocene and upper Pleistocene. Included in NM Statemap unit Q

LL-Lacustrine sediments of pluvial-lake San Agustín, undivided lake-plain, shoreline, and playa deposits; Holocene and uppermost Pleistocene. Included in NM Statemap unit Qpl. *Note: Restricted to San Agustin Plains area east of the Continental Divide*

PA-Piedmont-slope alluvium (undivided), including fan deposits and pediment veneers on slopes graded to base levels commonly independent of existing river-valley system; LFAs b, 5 and 6, as much as 100 ft (30m) thick; primarily in the vadose zone, but basal parts may be seasonally saturated or contain "perched-groundwater" bodies; Holocene to Middle Pleistocene. Includes NM Statemap units Qa and Qp

PAU-High-level remnants of piedmont alluvium most predating earliest stages of river-valley entrenchment (undivided older PA and UG1), including some landslide deposits; LFAs 5 to 6, usually less than 100 ft (<30m) thick; primarily in the vadose zone, but basal parts may be seasonally saturated or contain "perched-groundwater" bodies; lower Pleistocene and upper Pliocene. Includes NM Statemap unit QT

QTb-Younger basalt flow and vent units of Apache Creek and Gila-Colorado River Divide areas; primarily in the vadose zone, but basal parts may be seasonally saturated; lower Pleistocene and Pliocene. The Apache Creek flow (~1 Ma) caps high (~330-ft) strath terraces along lower Apache Creek and the downstream Tularosa River reach, and is inset into middle Gila Gp HSU-MG (Luedke and Smith 1978, Ratté 2001). QTb remnants in the San Francisco-Little Colorado Divide are mostly in north of the SFR basin. Includes NM Statemap and USGS quadmap units Qb, QTb, and Tnb

Gila Group HSUs (Neogene Intermontane Basin-Fill and Interbedded Volcanics)

UG1-Upper Gila Gp piedmont-slope alluvial deposits (LFAs 5 and 6), usually <100 ft (<30m) thick; entirely in the vadose zone; Lower Pleistocene and Pliocene. Includes NM Statemap unit QTp.

UMG-Upper and Middle Gila Gp (UG and MG-undivided): piedmont-slope alluvial and basin-floor (axial-stream) deposits, locally with capping and interbedded basaltic and silicic volcanics (QTb, Tb, and Tr); LFAs 4 to 6, usually <100 ft (<30m) thick; entirely in the vadose zone; Lower Pleistocene to Upper Miocene. Includes NM Statemap unit QTp. *Note: Primarily piedmont facies LFAs 5-6 (HSU-UG1),with Upper Gila Gp axial-stream facies (mainly LSF4) only preserved in Alma subbasin (Houser 1994) and in the Cactus Flat divide area south of Pleasanton (Mack 2004, Mack and Stout 2004)*

MG-Middle Gila Gp (undivided): piedmont-slope and basin-floor deposits, locally with capping and interbedded basaltic and silicic volcanics (Tb and Tr); LFAs 4 to 8, as much as 3,000 ft (900m) thick*; most of the unit comprises well-indurated conglomerates, sandstones and mudstones (LFAs 7 and 8) that are cemented with zeolites and some calcite; upper part usually in vadose zone, and the saturated zone forms a significant basin-fill aquifer-system component in many valley areas; Miocene (~6-20 Ma). Included in NM Statemap and USGS quadmap units QTg, Qtgu, and QTgl. **Notes: 1) Maximum thickness of about 3,000 ft penetrated by wells drilled in the lower SFR basin below Clifton, AZ (QTgs/Tgbr-Ferguson and Enders 2000); and 2) the lithofacies composition and chrono-stratigraphy of this map-unit complex has only been described in detail in the Reserve Graben, the Alma subbasin, and the Clifton-Morenci area (Crews 1994, Houser 1994, and Ferguson and Enders 2000)*

MG1-Middle Gila Gp piedmont-slope deposits, primarily LFAs 7 and 8, as much as 1,000 ft (300m) thick; locally capped with unit QTb1; mostly in vadose zone, and much of the saturated part comprises well-indurated conglomeratic sandstone beds (LFAs 7 and 8); upper Miocene. Includes NM Statemap unit Tfl (Fence Lake Fm of Chamberlin et al. 1994) and AZGS DGM-1 map unit Tgbr (Ferguson and Enders 2000)

Tb-Older basalt flow and vent units capping and interbedded with Middle and Lower Gila Gp HSUs; capping units primarily in the vadose zone; interbedded flow and vent units may form significant local aquifers where saturated; Pliocene to middle Miocene (Luedke and Smith 1978). Includes NM Statemap and USGS quadmap units QTb and Tnb

Tr-Rhyolite volcanic and some volcaniclastic rocks that are locally intercalated with Middle and Lower Gila Gp HSUs; includes undifferentiated trachytes and andesites in the Arizona White Mountain volcanic field; Miocene (Luedke and Smith 1978). Includes NM Statemap and USGS quadmap units Tnr and Tjr

MLG-Middle and Lower Gila Gp basin (undivided), primarily well-indurated LFAs 7 and 8, and some LFA 9, as much as 2,000 ft (600m) thick; capped by and/or interbedded with units Tb and Tr; basal part locally interbedded with unit Tba; saturated below level of floors of major stream valleys; middle Miocene to uppermost Oligocene. Included in NM Statemap unit QTg, USGS quadmap unit Tvc (Drewes et al. 1985), and AZGS DGM-1 map units Tgmc and Tbck (Ferguson and Enders 2000, cf. Heindl and McCullough 1961)

Paleogene Bedrock Units (Including Some Locally Significant Aquifer Systems*)

*Tba-Basaltic andesite to dacitic lava flows and vent units, as much as 600 ft (180m) thick; upper part locally interbedded with basal unit MLG; uppermost Oligocene. Included in NM Statemap and USGS quadmap unit Tuau (e.g. upper Mogollon Gp-Bearwallow Mountain Andesite of Marvin et al. 1987, Ratté 2001)

Trp-Rhyolite pyroclastic rocks mainly from Bursum caldera, with intercalated volcaniclastic sandstone and breccia; as much as 200 ft (60m) thick; upper Oligocene. Included in NM Statemap and USGS quadmap units Turp and Tbg (e.g. Mogollon Gp-Bloodgood Canyon Tuff of Elston 1976, Ratté 2001)

Tva- Andesitic and dacitic lava flows and vent units, with some intercalated volcaniclastic sediments; as much as 1,300 ft (400m) thick; Oligocene. Included in NM Statemap and USGS quadmap unit Tual (lower Mogollon Gp, Ratté 2001)

Trv-Silicic to intermediate-composition lavas. Mainly Rhyolite, dacite and latite domes and flows, with some ash-flow tuffs and andesite flows; Oligocene. Included in NM Statemap and USGS quadmap unit Turf

Tvu-Undivided basaltic to silicic volcanics, with some intercalated volcaniclastic rocks; undifferentiated unit in the Arizona and subsurface parts of cross-sections in New Mexico outside Bursum caldera; Oligocene and uppermost Eocene; primarily Tba/Trp-Tva/Trv/Tmrp correlatives. Included in Arizona Statemap unit Tv

*Tbvu-Undivided silicic to intermediate volcanics, with some intercalated volcaniclastic rocks; undifferentiated subsurface unit in Bursum caldera (cross-sections CC', DD', and E"E"); early Oligocene and late Eocene; primarily Tva/Trv/Tmrp correlatives.

Ti-Silicic and intermediate intrusive rocks-undivided; mostly Oligocene. Included in NM Statemap and USGS quadmap unit Ti

*Tmsc-Sedimentary rocks-undivided, mainly volcaniclastic sandstone and conglomerate, with some interbedded andesitic flows (Tma) and silicic tuffs; as much as 2,000 ft (600m) thick; early Oligocene to late Eocene. Included in NM Statemap and USGS quadmap units Ts, T os and Tvs (e.g. Spears Gp of Cather et al. 1994)

*Tma-Andesitic flow and vent units, and thin silicic tuffs that are interbedded with Tmsc (Spears Gp); andesites as much as 600 ft (180m) thick; early Oligocene to late Eocene. Included in NM Statemap and USGS quadmap unit Tla (includes andesite of Dry Leggett Canyon, Ratté 2001

*Tmrp-Rhyolite pyroclastic rocks, with intercalated volcaniclastic sandstone and breccia; as much as 700 ft (210m) thick; early Oligocene to late Eocene. Included in NM Statemap and USGS quadmap unit Tlrp (e.g. Kneeling Nun Tuff and Cooney Tuff of Elston 1976, and Ratté 2001, 2008)

*Tmvu-Undivided silicic to intermediate volcanics, with some intercalated volcaniclastic rocks; undifferentiated subsurface unit northwest of Bursum caldera (cross-sections BB' and CC'); primarily Tv/Tmsc-Tma correlatives.

Tlu-Undivided volcanic, and volcaniclastic and siliciclastic sedimentary rocks; undifferentiated subsurface unit on western wall of Bursum caldera (cross-sections DD' and E"E"); Eocene and early Oligocene; primarily Tmsc-Tma/Tls correlatives.

Tls-Sedimentary rocks, primarily siliciclastic sandstone, conglomerate, and mudstone exposed only in the Little Colorado River basin north of the Gila-Colorado Divide and east of the Continental Divide; may have aquifer potential in Spur Lake Basin and Dry Leggett Canyon areas; as much as 3,000 ft (900m) thick; Eocene. Included in NM Statemap and USGS quadmap unit Tps (e.g. Baca Fm of Cather et al. 1994, Chamberlin et al. 1994)

Tli-Silicic to mafic intrusive rocks of the Morenci mining district, AZ-undivided; Paleocene and early Eocene. Included in map units Tbx, Tp, Tpgy, Tpgo, Td, Tpm, and Tpd of Ferguson and Enders (2000)

Mesozoic to Proterozoic Bedrock Units in Clifton-Morenci (AZ) Subbasin of the SFR Basin (intruded by Tli, and may include some locally significant carbonate-rock aquifer systems*)

Ku-Sedimentary rocks-undivided, including quartzitic sandstone, siltstone and shale; upper Cretaceous. Included in AZ Statemap unit Ks

Pzu-Sedimentary rocks-undivided, mainly limestone, with some shale and quartzitic sandstone; Pennsylvanian and Mississippian. Included in AZ Statemap units Pz and MPt (Ferguson and Enders 2000).

*Pz- Sedimentary rocks-undivided, mainly dolomitic limestone, with some shale and quartzitic sandstone; mainly upper Cambrian to Mississippian. Included in AZ Statemap unit MЄ

XY-Crystalline intrusive and metasedimentary rocks-undivided, including granite, diorite, and schist; Proterozoic. Included in AZ Statemap units XYg and Xms

Legend

San Francisco River Watershed Boundary
Faults
Bursum Caldera Boundary
Canal or Ditch
River
Creek or Arroyo
Pipeline
Gaging Station

1:200,000
0 2.5 5 10 Miles
0 1,100 2,200 4,400 6,600 8,800 11,000 13,200 15,400 17,600 19,600 22,000 Meters

DATUM: Universal Transverse Mercator, Zone 13, NAD83, Clarke 1866.

COMPILED BY: New Mexico Water Resources Research Institute, New Mexico State University, Las Cruces, New Mexico, June 2009

Data Sources:

Basemap data from the New Mexico Resource Geographic Information System (RGIS), accessed online at http://rgis.unm.edu/

Hydrostratagraphic units modified from 1:1,000,000 scale Geologic Map of Arizona (2000) accessed online at: http://www.azgs.state.az.us/; and1:500,000 scale Geologic Map of New Mexico (2003) accessed online at: RGIS referenced above.

Streamflow and watershed boundary files from USGS National Hydrography Dataset (high resolution) watershed 1504004 accessed online at: http://nhd.usgs.gov/

Watershed subbasin boundaries derived from 1:100,000 scale topographic maps

Cited References

Basabilvazo, G.T. 1997. *Ground-water resources of Catron County, New Mexico*. U.S. Geological Survey, Water-Resources Investigations Report 96-4258. 141 p.

Cather, S.M., R.M. Chamberlin, and J.C. Ratté. 1994. Tertiary stratigraphy and nomenclature for western New Mexico and eastern Arizona. *New Mexico Geological Society Guidebook, 45th Field Conference*. 259-266.

Chapin, C.E., W.C. McIntosh, and R.M. Chamberlin. 2004. The late Eocene-Oligocene peak of Cenozoic volcanism in southwestern New Mexico. In The Geology of New mexico: A geologic history. Edited by G.H. Mack and K.J. Giles. New mexico Geological Society Special Publication 11. 271-293.

Chamberlin, R.M., S.M. Cather, O.J. Anderson, and D.E. Jones. 1994. Reconnaissance geologic map of the Quemado 60' x 30' quadrangle. New Mexico Bureau of Mines & Mineral Resources Open-File Report, scale 1:100,000.

Crews, S.G. 1994. Tectonic control of synrift sedimentation patterns, Reserve graben, southwestern New Mexico. *New Mexico Geological Society Guidebook*, 45th Field Conference. 125-134.

Drewes, H., B.B. Houser, D.C. Hedlund, D.H. Richter, C.H. Thorman, and T.L. Finnell. 1985. *Geologic map of the Silver City 1°x2° Quadrangle, New Mexico and Arizona*. U.S. Geological Survey Miscellaneous Investigations Series Map, I-1310-C, scale 1:250,000.

Elston, W.E. 1976. Glossary of stratigraphic terms of the Mogollon-Datil volcanic province. In *Cenozoic volcanism in southwestern New Mexico: A Volume in Memory of Rodney C. Rhodes, 1943-1975*. Edited by W.E. Elston and S.A. Northrop. New Mexico Geological Society Special Publication No. 5. p. 135-145.

Ferguson, C.A. and M.S. Enders, compilers. 2000. *Digital geologic map of the Clifton-Morenci area, Greenlee County, Arizona, v. 1*. Arizona Geological Survey, Digital geologic map DGM-01. CD-ROM; DGM-01,S-three color maps, scale 1:24,000. http://www.azgs.az.gov/publisy_2.shtml

Ferguson, C.A., M.S. Enders, L. Peters, and W.C. McIntosh. 2000. Mid-Tertiary geology and geochronology of the Clifton-Morenci area, Greenlee and Graham Counties, Arizona, Arizona Geological Survey, Open-file Report 00-07. 69 p. http://www.azgs.az.gov/publisy_2.shtml

Hawley, J.W. and Kernodle, J.M., 2000, Overview of the hydrogeology and geohydrology of the northern Rio Grande basin-Colorado, New Mexico, and Texas. In *Proceedings of the 44th Annual New Mexico Water Conference. The Rio Grande Compact: It's the Law!* Edited by C.T. Ortega Klett. New Mexico Water Resources Research Institute, Technical Report No. 312, New Mexico State University, Las Cruces, NM. 79-102. http://wrri.nmsu.edu/publish/watcon/proc/proc44/

Hawley, J.W., B.J. Hibbs, J.F. Kennedy, B.J. Creel, M.D. Remmenga, M. Johnson, M. Lee, and P. Dinterman. 2000. *Trans-International Boundary aquifers in southwestern New Mexico*. New Mexico Water Resources Research Institute, New Mexico State University, prepared for U.S. Environmental Protection Agency-Region 6 and International Boundary and Water Commission; Technical Completion Report-Interagency Contract X-996350-01-3. 126 p. http://wrri.nmsu.edu/publish

Heindl, L. A. and R.A. McCullough. 1961. *Geology and the availability of water in the lower Bonita Creek area, Graham County, Arizona*. U.S. Geological Survey, Water-Supply Paper 1589. 40 p.

Houser, B.B. 1987. *Geologic map of the Alma 7.5' quadrangle, Catron County, New Mexico*. U.S. Geological Survey, Geologic Quadrangle Map GQ-1610. scale 1:24,000.

Houser, B.B. 1994. Geology of the Late Cenozoic Alma Basin, New Mexico and Arizona. *New Mexico Geological Society Guidebook, 45th Field Conference*. 121-124.

Luedke, R.G. and R.L. Smith. 1978. *Map Showing Distribution, Composition, and Age of Late Cenozoic Volcanic Centers in Arizona and New Mexico*. U.S. Geological Survey Miscellaneous Investigations Map I-1091-A, scale 1:1,000,000.

Mack, G.H. 2004. Middle and late Cenozoic crustal extension, sedimentation, and volcanism in the southern Rio Grande rift, Basin and Range, and southern Transition Zone of southwestern New Mexico. In *The Geology of New Mexico: A geologic history*. Edited by G.H. Mack and K.J. Giles. New Mexico Geological Society Special Publication 11. 389-406.

Mack, G.H. and D.A. Stout. 2004. Unconventional distribution of facies in a continental rift basin: the Pliocene-Pleistocene Mangas Basin, southwestern New Mexico, USA. *Sedimentology* 52: 1187-1205.

Marvin, R.F., C.W. Naeser, M. Bikerman, H.H. Mehnert, and J.C. Ratté. 1987. *Isotopic ages of post-Paleocene rocks within and bordering the Clifton 1°x2° quadrangle, Arizona-New Mexico*. New Mexico Bureau of Mines and Mineral Resources Bulletin 118. 63 p.

New Mexico Bureau of Geology and Mineral Resources. 2003. *Geologic Map of New Mexico*. Scale 1:500,000. http://geoinfo.nmt.edu/publications/maps.html.

Ratté, J.C. 1989. Days 3 and 4: Selected volcanic features of the western Mogollon-Datil volcanic field. In *Field excursions to volcanic terranes in the western United States, Vol. I: Southern Rocky Mountain region*. Edited by C.E. Chapin and J. Zidek:. New Mexico Bureau of Mines and Mineral Resources Memoir 46, p. 68-91, 114-119.

Ratté, J.C. 2001. *Geologic map of the Tularosa Mountains 30' x 60' quadrangle, Catron County, New Mexico*. U.S. Geological Survey Geologic Investigations Series I-886. scale 1:100,000, with 13 p. pamphlet.

Ratté, J.C. 2008. *Geology along the Catwalk National Recreationa Trail near Glenwood New Mexico*. New Mexico Geological Society, 59th Annual Field Conference Guidebook. 17-26.

Richard, S.M., S.J. Reynolds, J.E. Spencer and P.A. Pearthree, compilers. 2000. *Geologic map of Arizona*. Arizona Geological Survey Map M-35, scale 1:1,000,000. http://www.azgs.state.az.us/services_azgeomap.shtml

Trauger, F.D. 1972. *Water Resources and General Geology of Grant County, New Mexico;* Hydrologic Report 2. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM. 211 p.

Witcher, J.C., W.R. Hahman and C.A. Swanberg. 1994. Alpine 1/Federal corehole-subsurface stratigraphy of the eastern White Mountains, Apache County, Arizona. *New Mexico Geological Society Guidebook, 45th Field Conference*. 233-240.

Plate 1. Hydrogeologic map of the San Francisco River basin region, west-central New Mexico, and east-central Arizona. Compiled and modified from Chamberlin et al. 1994, Ferguson and Enders 2000; Ferguson et al. 2000, Hawley et al. 2000; New Mexico Bureau of Geology and Mineral Resources (2003); Ratté 2001, 2008, unpublished; and Richard et al. 2000